

# The technical production, storage and conservation routes of chilli peppers (*Capsicum* spp.) produced in Benin and constraints impeding the development of the sector.

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## 1 ABSTRACT

Chilli pepper (*Capsicum* spp.) is an annual vegetable fruit used as a spice in almost all food and especially in all local dishes in Benin. However, it is neglected in many countries and relegated to the background which does not favor the agricultural development. As a result, its cultivation and conservation are still traditional and face many cultural and post-harvest constraints. The objective of this work is to make an investigation on the current state of the chilli pepper sector in Benin from the planting, growth, harvest until the transformation through storage and preservation. Overall, the review presents all the technical shortcomings hindering the opening of the sector on its socio-economic environment and to make recommendations for the improvement of the quality of chilli pepper sold and consumed in Benin. Thus, the results of this review indicate that there are several local varieties of chilli pepper grown in Benin belonging to three species of the Solanaceae family: *Capsicum chinense* (annual variety), *Capsicum annum* L. (annual variety) and *Capsicum frutescens* (perennial variety). Its production is generally in rainfed or irrigated crops, in truck farming or on mainland. The best farming technique is the one that begins with the nursery and its success depends on the quality of the plants resulting from this stage. The best methods of storage and preservation vouching a good sanitary quality of chilli pepper are still to be promoted. The main problem encountered by the tillage of chilli peppers in Benin is its contamination by mold during its production and storage. It is therefore important to follow the technical production, storage and preservation routes, to assess the susceptibility of chilli pepper to mold at each stage and to measure the mycotoxins throughout the production chain so as to vouch the safety of chilli pepper consumers and to develop the chilli pepper sector in Benin.

## 2 INTRODUCTION

Chilli pepper (*Capsicum* spp.) is the second market gardening crop after tomatoes in Benin (INRAB, 2009). It is not only rich in vitamins A, B6, C, E, K, in trace elements such as copper, iron, manganese and potassium, but also in ascorbic acid, flavonoids, oligosaccharides and carotenoid compounds (Orobiyi, 2015). Chilli pepper is among the first spices or food additives in the world. It is one of the most produced and consumed vegetable crops and undeniably occupies a place of choice in Beninese households. Several varieties of chilli pepper are used as fresh fruit directly from the fields; in dried fruit from the conservation and processed into paste or powder for the different foods cooking. In addition to food, chilli pepper is also used for its medicinal properties (FAO, 2016). In phyto-medicine, the fruit is used orally as an infusion to improve blood circulation, treat nausea, high blood pressure, diabetes and overweight (Lejeune *et al.*, 2003; Koffi and al. 2014). Its frequent use in the treatment of various diseases in a traditional environment may be justified by the fact that its extracts possess antimicrobial properties (Koffi *et al.*, 2014). Indeed, the main interest of chilli pepper is in its physico-chemical composition (Tilahun *et al.*, 2013). Its high antioxidant content, including capsaicin, gives it a high nutraceutical value (nutritional and medicinal). But this physico-chemical composition varies according to the

varieties and the environmental conditions (Bae *et al.*, 2012). In Benin, farmers grow chilli pepper for the household food supply and generate income. The production and trade of this speculation contribute to improving the stability of the food system and increasing the predictability of the source of income of potential producers and actors who export it (INRAB, 2009). The importance of this sector militated in favor of its inclusion in the Strategic Plan for Agricultural Sector Recovery (UNDP-BENIN-PANA 1, 2015). Chilli peppers are integrated into farmers' production systems in most parts of Benin. Despite the economic importance of chilli pepper, it remains very little studied by Beninese researchers. The few research projects carried out concern cultural practices, varietal improvement and agro-morphological characterization (INRAB, 2009; Orobiyi, 2015). The objective of this work is to draw up an inventory of the technical production routes, the methods of storing and preserving chilli peppers in Benin. A final chapter presents the main constraints to be raised in the chilli pepper sector in order to promote technical farming itineraries, standardized storage and conservation methods allowing a good sanitary quality of chilli pepper and the minimization of post-harvest losses caused by contaminants in the production chain so as to better this sector.

## 3 GENERALITY ON THE CHILLI PEPPER

**3.1 Systematic and cultivated chilli pepper varieties:** The chilli pepper belongs to the genus *Capsicum*, the Solanaceae family, the Solanales order, the Magnoliopsida class or Dicotyledonous and the Magnoliophyta branch (Akoègninou *et al.*, 2006). The genus *Capsicum* contains 27 species (Chaine-Dogimont, 1993) of which only 5 are domesticated worldwide (Costa *et al.*, 2009; Brown *et al.*, 2013). These are *C. annuum*, *C. chinense*, *C. frutescens*, and *C. baccatum* L. and *C. pubescens*. Only *C. annuum*, *C. chinense* and *C. frutescens* are cultivated in Benin, (Akoègninou *et*

*al.*, 2006). Chilli pepper is grown throughout Benin and mainly in the 6 southern departments that provide 70% of the national production (UNDP-BENIN-PANA 1, 2015). It is produced in home gardens, agricultural development areas, in pure culture or in combination with other crops such as tomato (*Solanum lycopersicum*), corn (*Zea mays*), groundnut (*Arachis hypogaea*), cowpea (*Vigna unguiculata* subsp. *Unguiculata*), soybean (*Glycine max*), cassava (*Manihot esculenta*), and yam (*Dioscorea dumetorum*). The production is made in rainfed, irrigated or off-season crops. Several

varieties of chilli pepper including small chilli peppers ("Salmon" and "Chilli pepper" or "Pili-pili"), large chilli peppers ("Gbotakin" or "Safi" and "Gros de Dalao"), medium chilli peppers ("Sucette de Provence" and "Jaune du Burkina-Faso") and the long chilli pepper "Cayenne" known as Glazoue or Nigeria chilli pepper, are grown in Benin. These varieties belong to the three species of the Solanaceae family: *Capsicum Chinense* (annual and conical variety), *Capsicum annuum* L. (annual and long variety) and *Capsicum frutescens* (perennial and very small variety). **3.2 Chilli pepper production**

**3.2.1. In the World:** The consumption of chilli peppers fruits (*Capsicum* spp.), probably ranked among the first spices or food additives

is constantly increasing worldwide. In recent years, world chilli pepper production has steadily increased from 10 769 000 tons in 1991 to 22 168 000 tons in 2002 (FAO, 2003), doubling in size within a decade. Too, the world production of chilli peppers was evaluated in 2012 by FAO to more than 31 million tons (FAO, 2014). FAO statistics estimate the global chilli pepper production at 38,415,621 tonnes in 2016 in cultivated territory of 3,737,635 ha (FAO, 2018). Several varieties are cultivated around the world. India is the largest producer of chilli peppers in the world that contribute 25% of the world's production. The Photo 1 below shows some chilli pepper varieties grown around the world.



**Photo 1:** Chilli varieties grown around the world (Shankar et al., 2014)

**3.2.2 In West Africa:** In Africa, Nigeria, Egypt and Ghana have a regular production found on the international market (FAO, 2006). West Africa alone produces 1,703,612 tons for an area of 290,574 ha (or 4,435% of world production). The largest producers in West Africa are Nigeria and Ghana, respectively ranked eighth and thirteenth in the world (FAO, 2016). The vast majority of chilli peppers produced in Africa are sold in local, regional (Senegal, Gambia, Liberia, Sierra Leone and Mali) and international markets

(Europe and North America). In Benin, there are several varieties that are cultivated throughout the national territory according to different farming techniques with cultivation methods more or less varied in market gardening as on the mainland. Benin ranks the 58th place on the world scale with a very low production that has been going up and down since 2000 until today.

**3.2.3 In Benin:** In Benin, the whole production in 2016 amounts to 176,536 tons (FAO, 2018) and still increases to this day. This

expansion is justified by the use of chilli pepper as an ingredient in the cooking of many food dishes and shows the chilli pepper as a strategic market gardening product for Benin. Despite this weakness and instability in annual production, Benin is one of the major producers of West Africa before countries like Niger, Burkina Faso, Mali, Côte d'Ivoire and Togo (FAO, 2016). In addition, in Benin, the price of a chilli pepper bag (bag containing 100 kg of maize) can raise up from 10,000 CFA francs during the period of abundance to 45,000 CFA francs in the shortage period

(Orobiyi, 2015). Chilli pepper cultivation is therefore an important source of income for producing households. Women are the main processors, traders and users of kitchens in Africa and benefit from the potential income of chilli pepper production. Chilli pepper culture therefore plays an important role in reducing poverty in developing countries.

**3.3 Characteristics of chilli pepper grown:** Several species of Chilli pepper are produced. The Table 1 presents the characteristics of the main species of chilli pepper grown in the the world.

**Table 1 :** Main characteristics of chilli pepper species grown in the world (INRAB, 2009)

Chilli pepper species	Principal Characteristics
<i>Capsicum chinense</i> Jacq.	Its fruits (2 to 6 per knot) are of various shapes, in lanterns, or very flat ribs, very pungent (up to 250,000 on the scale of Scoville) to sweet and very fragrant. The species is also renowned for its long harvest period, its almost zero pesticide requirements and its very significant cost of production. Its cycle varies between 80 and 120 days on average. Seeds are slow to germinate. The species is very popular in the rainy season for its vigor and its great resistance to anthracnose and virus diseases (Grubben et El Tahir, 2004).
<i>Capsicum frutescens</i> L.	Perennial species whose height of the plants depends on the climate, with fine foliage, flowers often in clusters inserted in pairs. The leaves are sometimes ovoid. The floral peduncle is right to flowering and the fruits are elongated conical (sometimes round), very pungent but scented little. They are easy to dry (Williams et al., 1991 ; De Witt et Bosland, 1993).
<i>Capsicum annum</i> L.	Annual species as the name suggests. In this species we usually find varieties with sweet fruits but also some varieties with pungent fruits (Messiaen, 1975 ; Greenleaf, 1986).
<i>Capsicum pubescens</i> Ruiz et Pav.	Characterized by its very hairy ovoid leaves (hence its name) and its blue flowers, its black and irregular seeds. The species is characteristic of high areas. Large perennial bush that can grow up to 3 m high. Its growth cycle is at least 120 days. Its fruits are dehydrated and do not keep well (Eshbaugh, 1977 ; Chaîne- Dogimont, 1993).
<i>Capsicum baccatum</i> L.	Species distinguished by its white corolla marked yellow herringbone and stamens free. It is mainly used as a condiment. It is characteristic of the Andes, zone in which one also meets its wild form. Its cycle is about 120 days and the plants of <i>C. baccatum</i> have because of their persistence, a shrub tendency. There are two wild forms in this group ( <i>baccatum</i> and <i>microcarpum</i> ) and a domesticated form ( <i>pendulum</i> ) (Pickersgill, 1971 ; De Witt et Bosland, 1993 ; Chaîne-Dogimont, 1993).

**3.4 Vernacular catalogue and morphological features of chilli peppers recognition grown in Benin:** The vernacular names of varieties registered in Benin vary from one village to another and from one ethnic area to another. Each village seems to have its own set of names. These observations, common in vernacular nomenclature, have already been reported in many crops such as fonio (*Digitaria exilis*) (Adoukonou-Sagbadja et al., 2006), traditional leafy vegetables (Adjatin et al., 2012), cassava (*Manihot esculenta*) (Kombo et al., 2012), cowpea (*Vigna unguiculata* subsp. *Unguiculata*) (Gbaguidi et al., 2013), the earth lens (*Macrotyloma geocarpum*) (Assogba et al., 2015) and

sorghum (*Sorghum bicolor*) (Dossou Aminon et al., 2015). Agro-morphological and molecular characterizations will clarify this problem of synonymy as indicated by Assogba and al. (2015) and Gbaguidi and al. (2015). According to Akoègninou and al. (2006), it is through the shape and size of the fruits that producers recognize the varieties of chilli pepper species they grow. These producers' knowledge on chilli pepper can be capitalized by taxonomists and geneticists as recommended by Dansi and al. (2010) on fonio, Gbaguidi and al. (2013) on cowpea and Kombo and al. (2012) on cassava. According to Orobiyi (2015), the three species of chilli pepper are widespread in Benin and

have been particularly observed in cultivation in almost all villages in southern, central and northern Benin. In fact, the characteristics of chilli peppers grown in Benin vary from one production area to another (Table 2). Cultivars or local varieties of the species *C. chinense* (Gbotakin in the local language) are very much loved by consumers (Photo 2). The local varieties of the *C. annuum* species (Takingaga or Afundja in local language) (Photo 3) and those

of the species *C. frutescens* (Danhometakin in local language) (Photo 4) are in their case very adapted to drying and as such, their post-harvest conservation for domestic use or sale at high cost during off-season is relatively easy. Of the two species with good technological conservation qualities, the species *C. frutescens* (Danhometakin) is uncommon and this is due to its very low productivity, unprofitable production and extremely pungent taste.

**Table 2:** Characteristics of different chilli pepper varieties grown in Benin and their production areas (INRAB, 2009)

Varieties (in local language)	Origin	Characteristics	Cycle (month)	Culture period	Adapted region	Susceptibility to pests	Yield (t/ha)
<b>Gbotakin</b> <b>Adologbo, Afundja, Adjatakin</b>	Local	Small medium or big, round, elongated, perfumed or not, spicy or not	3	July to March	From south to north	Average sensitivity	7 to 10
	Local	Long, spicy	3 to 4	July to January	From south to north	Very sensitive	3 to 5
<b>Accra takin</b>		Medium to long, spicy	3	July to January	South	Sensitive	3 to 7
<b>Bird chilli (Pili-Pili)</b>	Local	Very small, conical and verysharp	3 to 4	All year	Center	Tolerant	<1
<b>Glazoue</b>	Local	Long and conical	3	July to December	Center	Average sensitivity	3 to 5
<b>Elisee</b>	Old, introduced from Ivory Coast	Small conicalpepper, spicy	2 to 3	July to December	Center	Average sensitivity	1 to 2
<b>Tatasse (local pepper)</b>	Old introduced	Very big and elongatedsweet	3	July to December	North	Very sensitive	10 to 15
<b>Safi, yellow from Burkina</b>	Improve introduced	Big, round, very hot, yellow to redwhen ripe	4 to 5	July to December	North	Sensitive	5 to 10
<b>Salmon</b>	Improve introduced	Small, spicy	2 to 3	July to October	South, Center, North	Sensitive	3 to 5



**Photo 2:** Species varieties of *Capsicum chinense* (Gbotakin in local language)  
 [A] Gbotakin in the open field, [B] Gbotakin after harvest, [C] Gbotakin during storage.



**Photo 3:** Species varieties of *Capsicum annuum* (Afundja in the local language)  
 [A] Afundja in the open field, [B] Afundja after harvest, [C] Afundja after storage.



**Photo 4:** Species varieties of the *Capsicum frutescens* (Danhometakin)  
 [A] Danhometakin in the open field, [B] Danhometakin after harvest, [C] Danhometakin after storage.

**3.5 Chemical composition of chilli pepper:** The chemical composition of chilli pepper varies considerably depending on the type of cultivar, ecological conditions, harvest stage and post-harvest conservation (dry or fresh green or red fruit) (Tilahun *et al.*, 2013; Kumari *et al.*, 2014). Thus, the approximate chemical composition for 100 grams of fresh chilli pepper is shown in Table 3. Chilli pepper also contains oleoresin which gives the chilli pepper its aromatic odour (Jin *et al.*, 2009).

Drying results in a significant loss of carotene and thiamine and the disappearance of almost all vitamin C (Tilahun *et al.*, 2013). Capsaicin is the compound that gives the chilli pepper a tangy taste (Tundis *et al.*, 2013). It is an odourless, colourless and tasteless alkaloid complex that is concentrated in varying amounts (0.01 to 1.0% dry weight) in the placental tissue and pericarp of the fruit, but it is found in all fleshy parts of very pungent varieties (Tilahun *et al.*, 2013).

**Table 3:** Approximate chemical composition of 100 grams of fresh chilli pepper (variety *Capsicum chinense*) (Jin *et al.*, 2009)

Composition	Units	Value (100 g)
Water	g	74
Energy	KJ	395
Protein	g	4,1
Lipids	g	2,3
Carbohydrates	g	18
Fibers	g	6
Calcium	mg	58
Phosphorus	mg	101
Iron	mg	2,9
Carotene	µg	7140
Thiamin	mg	0,25
Riboflavin	mg	0,2
Niacin	mg	2,4
Ascorbic acid	mg	121

**3.6 Uses of chilli pepper:** Chilli peppers fruits are widely used in the diet. More than 40% of harvested chilli peppers are used in kitchens (Adetula and Olakojo, 2006). Indeed, chilli pepper fruits are eaten fresh, dried or processed. The most pungent forms, including the hot chilli pepper (*Capsicum annum*) and the bird chilli pepper (*Capsicum frutescens*), are consumed in very small quantities and considered as a spice for seasoning sauces and stimulating appetite. On the other hand, the less pungent forms (the West Indian chilli pepper) are used as a vegetable. However, there is no limit between the use of chilli pepper as a spice and as a vegetable (Grubben et Tahir, 2004). Chilli pepper is used in spice blends to give flavour to all kinds of dishes. Chilli pepper is an excellent source of vitamin A and C (Boland et Batavia, 2000). It is used in the industry as an ingredient in many products such as canned fish, ginger beer, and in some pharmaceuticals. Chilli pepper is widely used in traditional medicine. Hot chilli peppers cause a high salivation, participate in digestion and have a laxative effect. Capsaicin has antioxidant, antimutagenic, anticarcinogenic and immunosuppressive properties (Jin *et al.*, 2009). The use of intravesical capsaicin has led to a better understanding of the pathophysiology of hyperparakisis of paraplegic (Labat, 1996). Also, capsaicin has beneficial effects on energy metabolism and food intake in people who have lost weight (Guerrero, 2000). Hypocholesterolemic effects have been identified in oleoresin (Tilahun *et al.*, 2013). Chilli pepper powder was found to be effective in reducing the intensity of dyspeptic symptoms in a clinical trial on 30 patients with functional dyspepsia (Bortolotti *et al.*, 2002).

**3.7 Varietal diversity, distribution and extent of chilli pepper in Benin:** There is a great diversity in chilli pepper grown in Benin. This diversity could be explained by the fact that varietal introductions from the Republic of Togo and / or the flow of genes between different species of chilli pepper are high. It can

also be explained by the mixtures of different species of chilli pepper in culture. According to producers, the low diversity observed in some villages in Oueme (southern Benin) is due to a concentration of production on a small number of highly productive and economically profitable varieties. In the other villages of this department, the low diversity observed can be explained by the cultivated chilli pepper groups which prevents cross-group crosses responsible for the appearance of new genotypes. The Shannon index to measure species diversity has shown that southern and central Benin have moderate varietal diversity, while the north has high diversity. However, pockets of high varietal diversity exist in the Center and South (based on the spatial analysis of diversity carried out by the kriging method) and are observed in the Couffo, Mono and Collines departments. These results can be explained by the introduction of new chilli pepper varieties from the Federal Republic of Nigeria and the Republic of Togo. Unfortunately, pockets of high diversity have not been observed in the North where varietal diversity is high (according to the Shannon index). This result could be explained by the fact that there is no large variation in the number of varieties grown per village. The regions of Oueme, Plateau and Mallanville recognized as chilli pepper-producing areas in Benin should show considerable varietal diversity or the existence of a pocket of strong diversity, (Assogba-Komlan *et al.*, 2007). According to producers, the low diversity observed in some southern and northern regions of the country is also due to a concentration of production on a small number of highly productive and economically profitable varieties. The majority of the producers also cultivate the three groups of hot chilli peppers (small, long and round chilli peppers) reported in Benin by Akoègninou and al. (2006). This shows that the chilli pepper in each of these groups is of particular importance to producers and consumers, given the shelf life and the presence of aroma in their fruit.

## 4 TECHNICAL ITINERARY

**4.1 Cultivation technical itinerary of chilli pepper in Benin:** There are usually four chilli pepper farming systems: rainfed crops, recession crops, lowland crops and irrigated crops. In Benin, the farm size averages is 1.13 ha per farmer with the smallest acreage being 0.06 ha and the largest being 4 ha. Field operations include: field preparation, nursery installation and management, plant placement, crop management, harvesting and packaging, product storage and storage. Producers (market gardeners or farmers) often work individually. But in areas of high production, particularly valleys and urban or peri-urban areas, there are peasant organizations (village groups). They are production or service cooperatives (INRAB, 2009). The analysis of the ripening time of the fruits showed that there is no relationship between the maturation period of the varieties and the type of chilli pepper (*C. annum*, *C. chinense* and *C. frutescens*) grown. According to the producers, the chilli pepper maturation period is influenced by the soil moisture and fertility and the state of the sown seeds. With regard to soil fertilization, only a few producers use biological means such as organic bottom manures i.e. chicken droppings, cow dung, compost and peanut or cowpea fennel and Mucana leaves as green manure to increase the productivity of the chilli pepper they grow. The majority of producers produce chilli pepper with chemical fertilizers that have adverse environmental and health consequences for producers and consumers (Kumari *et al.*, 2014). With regard to plant health protection, the means of integrated struggle are very little known by the producers. These means of struggle must be encouraged to protect not only crops against pests and pathogens, but also the environment and the health of populations for sustainable agriculture. It is also important to note that at the country level, women are more active in chilli pepper production than men. They intervene at each level of production. It is a culture that does not require much physical effort and allows women to meet their daily needs. The chilli pepper culture

is done in four (4) stages, the most delicate of which is that of the nursery (INRAB, 2009). These different steps are summarized as follows:

**a. The nursery:** The chilli pepper production depends on the quality of the nursery stock; it is a delicate step and it is important to strictly follow the indications proposed in this document. Nursery time varies from 21 to 35 days depending on the variety, soil type, period and area of production.

**b. Seed Supply:** In traditional chilli pepper production, several varieties are grown simultaneously and the seeds come from the fruits taken from the previous harvest. This self-production of seeds is not recommended because it reduces the performance (yield, shape, colour.) of the variety thus multiplied.

**c. Establishment of the nursery:** The establishment of a nursery involves the succession of operations that are the delimitation of the area, the choice of the type of nursery, the preparation of the plot, fertilization of the soil, sowing and maintenance. The nursery is usually done on well calculated areas. The board intended for the nursery must be flat, sandy, well drained and rich in organic way. It must be installed in a sunny and ventilated area of the field, sheltered from the wind and as close as possible to a source of water to facilitate watering.

**d. Transplanting and Care of the culture:** This step consists in materializing the pockets on the plot to be transplanted with strings and stakes while avoiding the holes too deep of 3 to 4 cm. Then select vigorous seedlings and tear them off with the clod around the roots. Thoroughly compact the soil around the roots without damaging the collar of the seedling and, if possible, irrigate immediately after transplanting. The maintenance of the culture consists of operations of sacro-hump, irrigation, phytosanitary protection and fertilization of the soil.

**e. Harvest:** Fruit harvesting normally begins 3 months after transplantation on



several occasions (3-5 harvests) (Assogba *et al.*, 2009; Hakmaoui *et al.*, 2013). The fruit matures gradually taking a deep red colour (blood colour). Fruits on bright, sunny sides are the first to ripen compared to those in the shade and interior of the foliage. Partial dehydration of the fruits on the plants is recommended because the colour stability in the chilli pepper is better when the harvest is late. As maturity increases, the dry matter content increases along with the intensity of the colour. Harvesting should be early in the morning and should be avoided during or just after the rains (Hakmaoui *et al.*, 2013).

**4.2 Technical itineraries for drying, storage and conservation:** For all agri-food crops, the management of post-harvest losses is very important. Generally, chilli pepper harvest is spread over a maximum of 3 to 5 months depending on the variety (Assogba *et al.*, 2009; Hakmaoui *et al.*, 2013). Fresh fruits harvested and dried fruits are packed in baskets, basins and bags. The chilli pepper dried and then ground is packaged in particular in small transparent bottles perforated lid or not. Wet or dry milling and drying are the forms of chilli pepper processing. Wet milling is done with stone grinders or small moving grinders. Dry milling is done with the grain mills. Natural drying in the sun is often the artisanal process used in Benin (UNDP-BENIN-PANA 1, 2015). There are improved natural drying techniques using solar dryers equipped with a solar energy capture device. With regard to drying, storage and storage techniques, the information provided by the producers shows that: (i) The variety "Gbotakin" of the species *Capsicum Chinense* is difficult to preserve; (ii) The other varieties of chilli peppers (Takingaga or Afundja) of the species *Capsicum annuum* and (Danhometakin) of the species *Capsicum frutescens* are predisposed to drying. Among the different drying methods, we have:

**a. Traditional solar drying:** Natural sun drying is the process traditionally used by producers. It is usually done on the production site and consists of spreading, exposing to sunlight and wind and this for several days (8 to

10 days), and the fresh fruits of chilli pepper on the ground or on mats, racks, on the shoulder of paved roads or rooftops. To avoid rotting berries during solar drying, the fruits to be dried are first soaked in boiling water to destroy parasites and microorganisms and then drained into baskets. This drying process makes it possible to reduce the moisture content of the chilli pepper to between 14 and 12% in order to guarantee its preservation. It is simple and cheap (free energy); but it causes losses of vitamins and colour, and carries serious risks of contamination.

**b. Improved solar drying:** Improved natural drying techniques or drying by solar dryers (direct, indirect or mixed) overcomes the various disadvantages of traditional drying. The types of dryers available are traditional sun-improved drying using rail-mounted dryers, traditional shade-enhanced drying using sheltered dryers and improved drying using solar dryers.

**c. Packaging:** Dried fruits are stored in new or recycled polyethylene bags (used for rice for example) that can hold about 40 kg. Dried fruits are sometimes turned into powder and stored for sale. There is no infrastructure development for post-harvest chilli peppers in Benin (Assogba *et al.*, 2009; UNDP-BENIN-PANA 1, 2015). The forms of processing of chilli pepper are: milling and drying. We distinguish wet milling and dry milling. The products resulting from the processing of chilli pepper are: ground fresh chilli pepper, ground chilli pepper and whole dry chilli pepper. Wet milling is done in neighbourhoods and markets with stone grinders or small portable grinders. Dry milling is done in the grain mills. There is no doubt that the drying and storage methods used in Benin favor the contamination of preserved chilli peppers (Assogba *et al.*, 2009; UNDP-BENIN-PANA 1, 2015). The drying must be done according to the required standards and hygienic: adapted drying areas and clean to guarantee the sanitary quality of the finished product. Dried fruits are stored in new or recycled jute or polyethylene bags that can hold about 40 kg. These bags are kept in a

cool, ventilated area away from sunlight and light (Assogba *et al.*, 2009; Hakmaoui *et al.*,

2013; UNDP-BENIN-PANA 1, 2015).

## 5 DISTRIBUTION, CONSUMPTION AND MARKETING OF CHILLI PEPPERS IN BENIN

Chilli pepper is distributed nationally as whole fruit, fresh or dry, milled in a wet or dry state (Assogba *et al.*, 2009; UNDP-BENIN-PANA 1, 2015). Its pungent flavour is very popular for seasoning almost any dish in Benin. Part of the chilli pepper is exported mainly in the dry state in West African countries. Chilli peppers are widely distributed in Benin because of their importance in the diet (Assogba *et al.*, 2009). This distribution is the work of resellers from the main markets who have a close relationship with retailers. Merchants in consumer markets, retailers source from secondary markets or from wholesalers and redistribute them to consumers down the production chain in rural areas and cities of Benin. Packaging is the 50 kg to 65 kg basket for products resold in Benin cities and 80 to 100 kg for baskets going to

Nigeria, Niger and Togo. Foreign consumers in West Africa are mainly Nigeria for chilli pepper marketed fresh by informal channels from areas of high production of Oueme. The dry chilli pepper is exported actively to Niger, Togo, Senegal and Gabon. Ground chilli packed in small bags and transparent bottles is exposed with other condiments such as tomato (*Solanum lycopersicum*), onion (*Allium cepa*), other spices and salt on display in consumer markets and sold to housewives. After the tomato, chilli pepper is the most popular condiment in urban Benin for consumption. The round chilli pepper is often used fresh and whole in sauces, because of its very pleasant aroma. Photo 5 shows the different forms of use and direct consumption of chilli peppers in Benin.



**Photo 5:** Forms of use and direct consumption of chilli pepper in Benin.  
[A] Fresh chilli, [B] Ground in the wet state, [C] Chilli powder.

## 6 CONSTRAINTS RELATED TO THE PRODUCTION OF CHILLI PEPPER

Fifteen constraints affect chilli pepper production in Benin (Orobiyi, 2015). Among them, the most important are soil poverty, insect attack, low productivity, plant organ drop (leaves, flowers and fruits) and drought. Then come virosis, anthracnose, damping-off, low shelf life, harvesting difficulties, lack of quality seed, low market value, lack of market flow, sensitivity to excess soil moisture and root and crown rot. The importance of constraints also varies from one agro-ecological zone to another (Orobiyi, 2015). In the North, the most

important constraints are: drought, soil poverty and low productivity. On the other hand, in Central Benin the main constraints enumerated by producers are the early fall of plant organs, low productivity and insect attack. In the south, insect attack, virosis, early plant drop, damping-off and anthracnose are the main constraints. There are also abiotic constraints that usually result in a decrease in yield of chilli pepper plants (Goldberg, 2004). The causes of this decline are many. Table 4 and Table 5 present the constraints related to the production of

chilli peppers in Benin and the variation in the importance and number of constraints related

to the production of chilli peppers in the agro-ecological zones of Benin.

**Table 4:** Constraints related to chilli pepper production in Benin (Orobiyi, 2015)

Constraints	North IMP (%)	Center IMP (%)	South IMP (%)
Drought	17,79	8,42	-
Poverty of the soil	17,06	11,78	6,83
Low productivity	16,95	13,8	1,55
Falling organs	12,11	14,81	13,67
Attack of insects	11,68	12,46	25,81
Viroses	6,74	7,41	15,84
Anthracnose (fruit rot)	6,11	4,38	13,04
Lack of quality seeds	2,21	2,36	-
Low shelf life	1,89	6,06	8,39
Sowing	1,47	2,36	13,32
Difficult harvest	1,47	5,05	-
Sensitivity to excess moisture	1,26	2,36	0,62
Low market value	2,42	7,74	-
Root and crown rot	0,84	1,01	0,93

*NTV*: Total number of villages in which the constraint is quoted;

*PCO*: Main Constraints or number of villages in which the constraint is ranked among the top five;

*CMAJ*: Major Constraints or number of villages in which the constraint is ranked first;

*IMP*: Importance of a constraint.

**Table 5:** Variation in the importance and number of constraints related to chili production in agro-ecological zones (Orobiyi, 2015)

Constraints	NTV	PCO	CMAJ	IMP (%)	Rank
Poverty of the soil	106	88	25	14,08	1
Attack of insects	112	81	22	13, 83	2
Low productivity	95	73	39	13, 31	3
Falling organs	108	76	19	13, 05	4
Drought	88	78	28	12,48	5
Viroses	62	57	18	8,81	6
Anthracnose (fruit rot)	57	48	8	7,27	7
Sowing	32	24	10	4,24	8
Low shelf life	41	13	9	4,05	9
Difficult harvest	21	7	1	1,86	10
Lack of quality seeds	21	6	1	1,80	11
Low market value	21	2	0	1,48	12
Lack of flow market	18	5	0	1,48	13
Sensitivity to excess soil moisture	17	3	1	1,35	14
Root and crown rot	11	3	0	0,90	15

*NTV*: Total number of villages in which the constraint is quoted ;

*PCO*: Main Constraints or number of villages in which the constraint is ranked among the top five ;

*CMAJ*: Major Constraints or number of villages in which the constraint is ranked first ;

*IMP*: Importance of a constraint.

## 7 FUNGAL DISEASES

With regard to fungal diseases, different types of attack are distinguished: powdery mildew or leaf white, fruit anthracnose, leaf Sigatoka, velvet leaf spot, crown rot and semis melt (Photo 6). Of these six diseases, white or powdery mildew is the most widespread in tropical Africa. It is caused by the fungus *Leveillula taurica* which grows on the underside

of the leaves causing chlorotic spots on the upper side, as in tomato. The development of the fungus is especially favoured by warm weather (20 ° C to 28 ° C) and moderate drought (50 to 75% relative humidity). Infection is followed by necrosis and severe leaf drop, which increases the risk of sunburn and secondary fruit rots (Shankar *et al.*, 2014). The

viral complex is also a dangerous disease for the young plant (INRAB, 2009; Shankar *et al.*, 2014). It consists of an attack of the plant by several types of virus. It is manifested by dwarfism: the plants are very little developed, the leaves are reduced, tense and discoloured. These plants carry very few flowers and fruits. Other fungal diseases occur mainly in the rainy season (Syukur *et al.*, 2013). Anthracnose or fruit rot caused by *Colletotrichum gloeosporioides* and to a lesser extent by *Colletotrichum capsici*, which is a major problem in ripe fruit especially on wetlands, causing yield losses of up to 90%. Leaf Sigatoka and velvet leaf spot caused by *Cercospora capsici* and *Cercospora unamunoi* respectively

cause total defoliation of the plant (Sanogo 2003; Shankar *et al.*, 2014). Downy mildew or crown rot caused by *Phytophthora capsici* affects all parts of the plant and is a very serious disease that greatly reduces the yield of growers (Jianhua *et al.*, 1998; Shankar *et al.*, 2014). Seedling or root rot is caused by *Pythium* spp and *Fusarium* spp. It causes no emergence of seedlings or sudden death of young plants (Declert, 1990). Post-harvest rots can be reduced by harvesting fruit in the dry season, reducing injury during handling and keeping it at cool temperatures (Shankar *et al.*, 2014). Fruit washing can increase the rate of infected fruits, but losses can be reduced by adding chlorine to the wash water and drying the fruit.



**Photo 6:** Some main diseases in the field of chilli pepper (Orobiyi, 2015)  
[A] Bacterial wilt of chilli pepper fruits (*Capsicum chinense* variety), [B] Anthracnose of chilli pepper fruits (*Capsicum annuum* variety), [C] Soft rot of chilli pepper fruits (*Capsicum chinense* variety).

## 8 PROFILE AND MICROBIOLOGICAL QUALITY OF CHILLI PEPPER

The presence of fungal contaminants on chilli peppers varieties is effective. Chilli pepper are likely to be contaminated with toxigenic fungi in fields, after harvest, during transport and during storage (FAO / WHO, 2017). Indeed, the cultivation techniques used could have an impact on the chilli pepper contamination in the field, especially in the humid lowlands. Also, improper storage or preservation methods used and the unsuitability of certain varieties for conservation would also lead to attacks by micro-organisms including fungi including molds of the genus *Aspergillus*, *Penicillium*, *Fusarium* and *Alternaria* (Zinedine, 2004; Nguyen, 2007; Debode *et al.*, 2016). Molds are heterotrophic eukaryotic or

multicellular multi-cellular fungi with a complex structure, endowed with the power of sporulation, developing on the surface of foodstuffs because of their aerobic nature (Meile, 2017). They are the most well-known contaminants in chilli peppers. Once on the chilli pepper, these micro-organisms alter the sanitary quality thus causing enormous economic losses (INRAB, 2009). Generally, contamination evolves after harvest, storage or storage based on a combination of intrinsic and extrinsic factors (Royer and Tap, 2004). There is no doubt that molds have a remarkable ability to adapt; a change in a technological process can lead to a quantitative and qualitative change in the mycoflora. Previous

studies have confirmed the presence of fungal agents including *Rhizoctonia solani*, *Colletotrichum* sp. and *Fusarium* sp. strongly identified on chilli pepper (Fondio *et al.*, 2015). A large number of mold species belonging mainly to the three very common genera *Aspergillus*, *Penicillium*, *Fusarium* (Zinedine, 2004; Nguyen, 2007; Debode *et al.*, 2016), present in ambient air, soil, on agricultural crops are able, for example developing on certain substrates such as peanuts, spices, coffee, rice, cereals and cereal products, grapes, fruits, millet and sorghum to synthesize and excrete mycotoxins (Nguyen, 2007; Garba *et al.*, 2014). Mycotoxins are products of the secondary metabolism of various molds that can be very toxic for humans and animals (Meile, 2017). It has been found that the same mycotoxin can be produced by various fungal species but not necessarily by all the strains belonging to the same species. Similarly, in some cases, the same species of fungus can produce several mycotoxins (Meile, 2017). They can grow on plants in the field or during storage. About 25% of the world's food crops are attacked by mycotoxin-producing molds (FAO, 2008). Estimated total losses of food commodities due to mycotoxins are estimated at nearly 1 000 million tonnes per year (FAO, 2008). The mode of mycotoxin production is complex: the same mold can produce different mycotoxins and the same mycotoxin can be produced by different molds. The factors triggering the production of mycotoxins are not yet well understood: a mold can be widely present on a commodity without secreting mycotoxins or little present and secrete mycotoxins in abundance. Productive mold can also disappear from the food, while mycotoxins, which are very stable, can persist even after heat treatment (Debode *et al.*, 2016).

In terms of public health, the main mycotoxins considered are aflatoxins (B1, B2, G1 and G2), ochratoxin A (OTA), fumonisins (B1 and B2), certain trichothecenes (nivalenol-NIV, deoxynivalenol-DON, diacetoxyscirpelo-DAS, fusarenone X, T2, HT2), patulin and zearalenone (Debode *et al.*, 2016; Meile, 2017). The single or combined cytotoxic and genotoxic effects of these molecules have been demonstrated in several studies (Golli-Bennour, 2010; Houmairi and Hicham, 2015). The mechanism by which this toxin induces cancer is not fully understood and is the subject of debate (Manderville, 2005; Turesky, 2005; Pfohl-Leszkowicz and Manderville, 2007). Carcinogenic substances can act according to two types of mechanism: a genotoxic mechanism (capable of causing damage to DNA) or an epigenetic mechanism. The term epigenetic defines the transmissible and reversible modifications of gene expression that are not accompanied by changes in nucleotide sequences. Taking into account the effects of cumulation and synergy of these molecules in the body, it is essential that preventive means such as the choice of chilli pepper of good quality to purchase and their good conservation under conditions of temperature and humidity moisture are a general strategy for consumer protection (Houmairi and Hicham, 2015). Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) and Good Storage Practices (GEPs) could help minimize mycotoxin contamination during all stages of chilli pepper production from primary production to for use by the consumer. It is advisable to apply GAP, GMP and BEP for pre-harvest, during processing and storage respectively (FAO / WHO, 2017). The table 6 presents the risks of toxicity caused by the main mycotoxins.

**Table 6:** Risks of toxicity caused by the main mycotoxins (Meilé, 2017)

Toxin	Effets	Cellular and molecular mechanisms of action
<b>Aflatoxin B1 + M1</b>	<ul style="list-style-type: none"> <li>- Hepatotoxicity</li> <li>- Genotoxicity</li> <li>- Carcinogenicity</li> <li>- Immunomodulation</li> </ul>	<ul style="list-style-type: none"> <li>- DNA adduct formation</li> <li>- Lipid peroxidation</li> <li>- Bioactivation by cytochromes P450</li> <li>- Conjugation with Glutathione transferases</li> </ul>
<b>Ochratoxin A</b>	<ul style="list-style-type: none"> <li>- Nephrotoxicity</li> <li>- Genotoxicity</li> <li>- Immunomodulation</li> </ul>	<ul style="list-style-type: none"> <li>- Impact on protein synthesis</li> <li>- Inhibition of ATP production</li> <li>- Detoxification by peptidases</li> </ul>
<b>Patulin</b>	<ul style="list-style-type: none"> <li>- Neurotoxicity</li> <li>- In vitro mutagenesis</li> </ul>	<ul style="list-style-type: none"> <li>- Indirect inhibition of enzymes</li> </ul>
<b>Trichothecenes (groups A and B)</b>	<ul style="list-style-type: none"> <li>- Hematotoxicity</li> <li>- Immunomodulation</li> <li>- Skin toxicity</li> </ul>	<ul style="list-style-type: none"> <li>- Induction of apoptosis on hematopoietic progenitor and immune cells</li> <li>- Impact on protein synthesis</li> <li>- Alteration of immunoglobulins</li> </ul>
<b>Zearalenone</b>	<ul style="list-style-type: none"> <li>- Fertility and Reproduction</li> </ul>	<ul style="list-style-type: none"> <li>- Estrogen receptor binding</li> <li>- Bioactivation by dehydrogenases</li> <li>- Conjugation with glucuronyltransferase</li> </ul>
<b>Fumonisin B1</b>	<ul style="list-style-type: none"> <li>- Central nervous system damage</li> <li>- Hepatotoxicity</li> <li>- Genotoxicity</li> </ul>	<ul style="list-style-type: none"> <li>- Inhibition of ceramide synthesis</li> <li>- Alteration of the sphinganine / sphingosine ratio</li> <li>- Alteration of the cell cycle</li> </ul>

## 9 CONCLUSION

This bibliographic review has carried out a detailed diagnosis of the current state of the chilli pepper industry in Benin, from the installation of the crop to the transformation of production with the essential aim of listing all the failures techniques hindering the opening of the sector on its socio-economic environment and to propose recommendations for improvements in the sanitary quality of this crop. The chilli pepper is today, the most consumed spice, entering almost all food and especially in all local dishes in Benin. In general, the agricultural constraints linked to the technical cultivation routes favor the contamination of the plant at different stages by diseases caused by the different micro-organisms including bacteria, viruses and especially fungi. Based on all the intrinsic and extrinsic factors, this contamination continues after harvesting until the spice is placed on the market, sometimes passing through the storage

and preservation stage. While taking into account the achievements already made by research in this area, it is in the perspective of removing the main constraints that undermine the chilli pepper sector and promote technical crop routes and standardized storage and storage methods allowing obtaining good quality chilli pepper chilli pepper and minimizing post-harvest economic losses that this work has been initiated. This review also presents the byproducts resulting from the transformation of the chilli pepper that must be exploited to the best advantage in order to develop the chilli pepper sector in Benin and constitutes upstream a part of the future works which will concern the project entitled: Technical itineraries, susceptibility to mold and determination of mycotoxins in the chilli pepper production chain (*Capsicum* spp.) in Benin.

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